Max CO_2 Reduction of Kerosene Fueled Turbofan Aircraft

LaRC/LeRC Intercenter Systems Analysis Team

C. Quinn

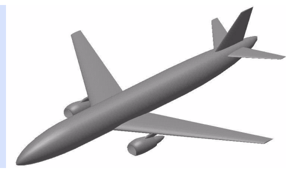
Study Approach

- Determine the "ultimate" CO_2 reduction possible of a conventional subsonic transport with turbofans
- Start with "2020 Scenario" Aircraft
- Push performance "to the limit" of what is theoretically possible

Max CO_2 Reduction with Kerosene Fuel

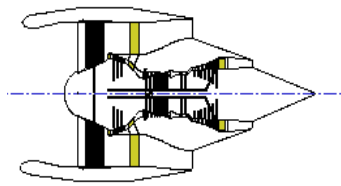
Airframe Assumptions

Comparison of "Scenario" and "Scenario +" Airframes



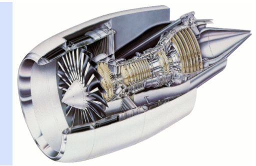
Technology	"Scenario" Benefit	"Scenario +" Benefit
Aerodynamics		
Improved and/or Simplified High-Lift System	+5% C_{Lmax}	+10% C_{Lmax}
Laminar Flow Control (nacelles and lifting surfaces)	30-35% Laminar Flow, +100% Air Cond. Wt.	100% Laminar Flow, no weight penalty
Interference, Excrescence, and Form Drag Reduction	-4.5% C_{Do}	-7% C_{Do}
Structures		
Composite Wing & Tails	-25% Wing & Tail Weight	-35% Wing & Tail Weight
Composite Fuselage	-25% Fuselage Weight	-35% Fuselage Weight
Light Weight Landing Gear	-20% Landing Gear Weight	-30% Landing Gear Weight
Advanced Metals	-5% Wing, Tail, Fuselage, Gear Weight	same
Aeroelastic Tailoring	Increased Aspect Ratio (to 13)	same
Systems		
Relaxed Static Stability	-5% C_{Di}	same
All Flying Control Surfaces	-30% Tail Area, +25% Pivot Weight	same
Fly-By-Light/Power-By-Wire	-100% Hydraulics Wt., No Engine Bleed	same
High Performance Navigation (All Weather)	Eliminate Alternate Airport Reserve	same
Intelligent Flight Systems	-50% Flt. Crew Weight, +5% Electrical Wt.	-50% Flt. Crew Weight, no penalty

Design Approach for High Efficiency JP Fueled Turbofan Engine



- Start with 2020 engine technology
- Increase component efficiencies
- Decrease internal duct losses
- Eliminate cooling
- Decrease pressure drop in combustor
- Increase overall pressure ratio
- Maintain two spool configuration
- Maintain nozzle jet velocity ratio

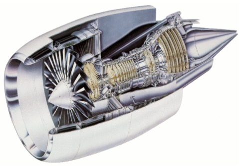
High Efficiency JP Fueled Turbofan Engine



Two Spooled Separate Flow Turbofan

Component Polytropic Efficiencies	0.98 – 0.99
Internal Duct Losses	3.5 - 4.5%
Combustor dP/P	0.025
Overall Pressure Ratio	100

325 Pax Engine Parameters



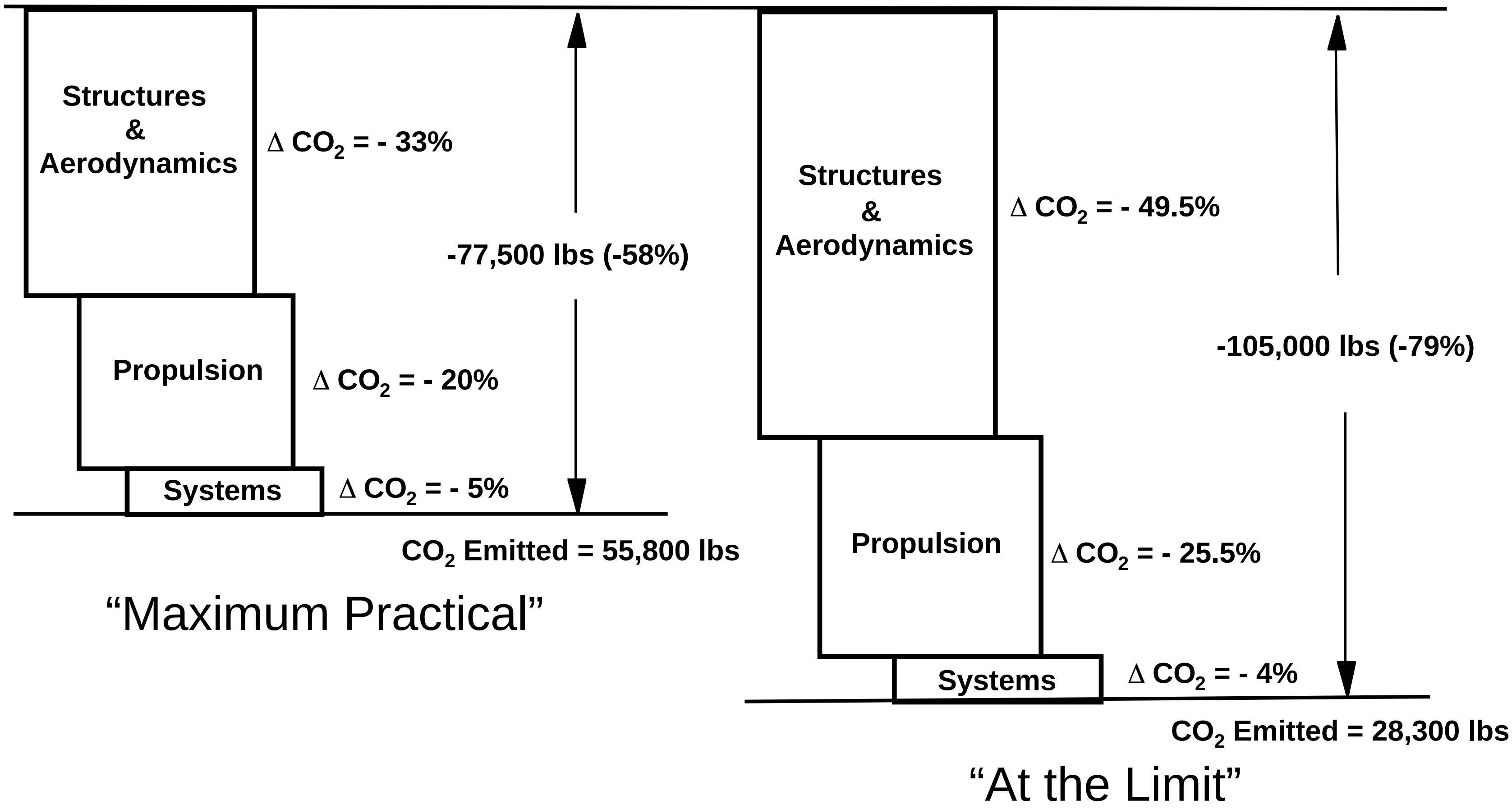
	Baseline	2020	High Eff
FPR	1.5	1.4	1.4
BPR	8	20	22.5
OPR	38	60	100
T4 (deg R)	3260	3800	3500
TSFC	.548	.432	.340
Cooling	19%	11%	no

325 PAX CONVENTIONAL SUBSONIC TRANSPORT

2-Engine, 6500 nmi Design Range, 10000 ft Field Length

CO_2 Reduction “Waterfalls” (1500nmi mission)

1995 EIS Technology: CO_2 Emitted = 133,300 lbs



Max CO_2 Reduction with Kerosene Fuel

Technology Level	Aircraft Type	Fuel Consumption kg/ASM	% Reduction
1995 (Baseline)	100 Pax Conventional	0.0471	-
	325 Pax Conventional	0.0341	-
	800 Pax Conventional	0.0323	-
	800 Pax BWB	0.0257	-
"Maximum Practical " ("Scenario " technology)	100 Pax Conventional	0.0236	-50
	325 Pax Conventional	0.0143	-58
	800 Pax Conventional	0.0113	-65
	800 Pax BWB	0.0085	-67
"Scenario " Airframe & "High Eff." Engine	100 Pax Conventional	0.0171	-64
	325 Pax Conventional	0.0111	-67
	800 Pax Conventional	0.0087	-73
	800 Pax BWB	0.0067	-74
"Scenario + " Airframe & "High Eff." Engine	100 Pax Conventional	0.0128	-73
	325 Pax Conventional	0.0072	-79
	800 Pax Conventional	0.0055	-83
	800 Pax BWB	0.0047	-82

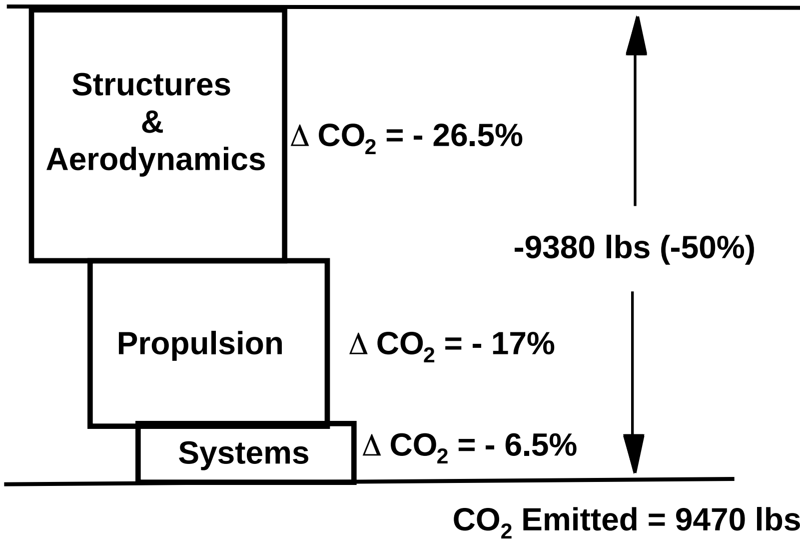
"Scenario +" airframe includes additional 10-15% reduction in wing, fuselage, tail, and landing gear weights; 100% laminar flow on lifting surfaces and nacelle with no system penalty (~30% with weight penalty in scenario vehicle); additional reductions in excresence and form drag; additional 5% increase in C_{Lmax}

100 PAX CONVENTIONAL SUBSONIC TRANSPORT

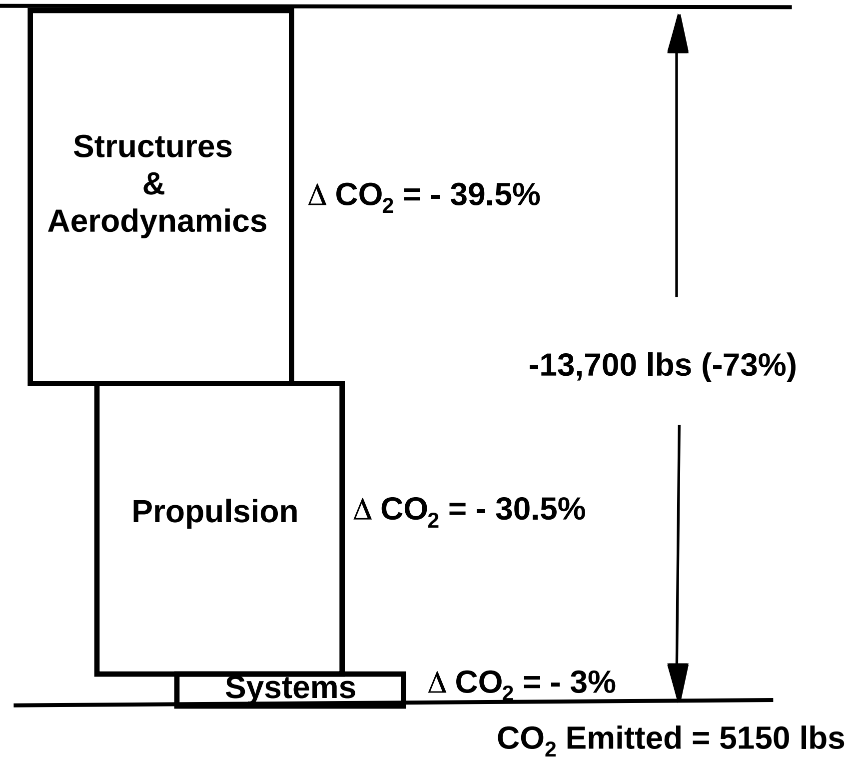
2-Engine, 1500 nmi Design Range, 10000 ft Field Length

CO_2 Reduction "Waterfalls" (500nmi mission)

1997 Technology: CO_2 Emitted = 18,850 lbs



"Maximum Practical"



"At the Limit"

800 PAX CONVENTIONAL SUBSONIC TRANSPORT

4-Engine, 8500 nmi Design Range, 10000 ft Field Length

CO_2 Reduction "Waterfalls" (3000nmi mission)

1995 EIS Technology: CO_2 Emitted = 620,000 lbs